
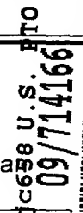


<div style="display: flex; justify-content: space-between;"><div style="width: 40%;"><div style="writing-mode: vertical-rl; transform: rotate(180deg);">11/17/00 3523 U.S. PTO</div></div><div style="width: 55%; text-align: center;">UTILITY PATENT APPLICATION TRANSMITTAL (Large Entity) <i>(Only for new nonprovisional applications under 37 CFR 1.53(b))</i></div></div> <div style="text-align: center; margin-top: 10px;">TO THE ASSISTANT COMMISSIONER FOR PATENTS Box Patent Application Washington, D.C. 20231</div>	<div style="border: 1px solid black; padding: 2px; margin-bottom: 5px;">Docket No. 1559A1</div> <div style="border: 1px solid black; padding: 2px;">Total Pages in this Submission 38</div>
	<div style="display: flex; justify-content: space-between;"><div style="width: 40%;"><div style="writing-mode: vertical-rl; transform: rotate(180deg);">11/17/00 3638 U.S. PTO 09/714166</div></div><div style="width: 55%;"></div></div>

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application for an invention entitled:

LOW SHADING COEFFICIENT AND LOW EMISSIVITY COATINGS AND COATED ARTICLES

and invented by:

Paul A. Medwick, Russell C. Criss, Mehran Arbab and James J. Finley

If a **CONTINUATION APPLICATION**, check appropriate box and supply the requisite information:

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: _____

Which is a:

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: _____

Which is a:

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: _____

☒ This application claims the benefits of U.S. Provisional Application No. 60/167,386.

Enclosed are:

Application Elements

1. ☒ Filing fee as calculated and transmitted as described below
2. ☒ Specification having 29 pages and including the following:
 - a. ☒ Descriptive Title of the Invention
 - b. ☒ Cross References to Related Applications *(if applicable)*
 - c. ☐ Statement Regarding Federally-sponsored Research/Development *(if applicable)*
 - d. ☐ Reference to Microfiche Appendix *(if applicable)*
 - e. ☒ Background of the Invention
 - f. ☒ Brief Summary of the Invention
 - g. ☒ Brief Description of the Drawings *(if drawings filed)*
 - h. ☒ Detailed Description
 - i. ☒ Claim(s) as Classified Below
 - j. ☒ Abstract of the Disclosure

UTILITY PATENT APPLICATION TRANSMITTAL
(Large Entity)

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Docket No.
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Total Pages in this Submission
38

Application Elements (Continued)

3. ☒ Drawing(s) *(when necessary as prescribed by 35 USC 113)*
- a. ☐ Formal Number of Sheets _____
- b. ☒ Informal Number of Sheets 1
4. ☒ Oath or Declaration
- a. ☐ Newly executed *(original or copy)* ☒ Unexecuted
- b. ☐ Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional application only)*
- c. ☒ With Power of Attorney ☐ Without Power of Attorney
- d. ☐ DELETION OF INVENTOR(S)
Signed statement attached deleting inventor(s) named in the prior application,
see 37 C.F.R. 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation By Reference *(usable if Box 4b is checked)*
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. ☐ Computer Program in Microfiche *(Appendix)*
7. ☐ Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all must be included)*
- a. ☐ Paper Copy
- b. ☐ Computer Readable Copy *(identical to computer copy)*
- c. ☐ Statement Verifying Identical Paper and Computer Readable Copy

Accompanying Application Parts

8. ☐ Assignment Papers *(cover sheet & document(s))*
9. ☐ 37 CFR 3.73(B) Statement *(when there is an assignee)*
10. ☐ English Translation Document *(if applicable)*
11. ☐ Information Disclosure Statement/PTO-1449 ☐ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☒ Acknowledgment postcard
14. ☐ Certificate of Mailing
- ☐ First Class ☐ Express Mail *(Specify Label No.):* _____

UTILITY PATENT APPLICATION TRANSMITTAL
(Large Entity)

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Docket No.
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Total Pages in this Submission
38

Accompanying Application Parts (Continued)

15. ☐ Certified Copy of Priority Document(s) *(if foreign priority is claimed)*

16. ☐ Additional Enclosures *(please identify below):*

Request That Application Not Be Published Pursuant To 35 U.S.C. 122(b)(2)

17. ☐ Pursuant to 35 U.S.C. 122(b)(2), Applicant hereby requests that this patent application not be published pursuant to 35 U.S.C. 122(b)(1). Applicant hereby certifies that the invention disclosed in this application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication of applications 18 months after filing of the application.

Warning

An applicant who makes a request not to publish, but who subsequently files in a foreign country or under a multilateral international agreement specified in 35 U.S.C. 122(b)(2)(B)(i), must notify the Director of such filing not later than 45 days after the date of the filing of such foreign or international application. A failure of the applicant to provide such notice within the prescribed period shall result in the application being regarded as abandoned, unless it is shown to the satisfaction of the Director that the delay in submitting the notice was unintentional.

UTILITY PATENT APPLICATION TRANSMITTAL
(Large Entity)

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Docket No.
1559A1

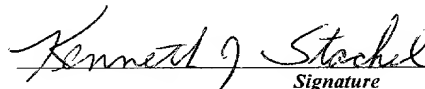
Total Pages in this Submission
38

Fee Calculation and Transmittal

CLAIMS AS FILED

For	#Filed	#Allowed	#Extra	Rate	Fee
Total Claims	38	- 20 =	18	x \$18.00	\$324.00
Indep. Claims	3	- 3 =	0	x \$80.00	\$0.00
Multiple Dependent Claims (check if applicable) <input type="checkbox"/>					\$0.00
BASIC FEE					\$710.00
OTHER FEE (specify purpose) _____					\$0.00
TOTAL FILING FEE					\$1,034.00

- ☐ A check in the amount of _____ to cover the filing fee is enclosed.
- ☒ The Commissioner is hereby authorized to charge and credit Deposit Account No. 16-2025 as described below. A duplicate copy of this sheet is enclosed.
- ☒ Charge the amount of **\$1,034.00** as filing fee.
 - ☒ Credit any overpayment.
 - ☒ Charge any additional filing fees required under 37 C.F.R. 1.16 and 1.17.
 - ☐ Charge the issue fee set in 37 C.F.R. 1.18 at the mailing of the Notice of Allowance, pursuant to 37 C.F.R. 1.311(b).


Signature

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Dated: November 16, 2000

Pittsburgh, Pennsylvania
cc:

**LOW SHADING COEFFICIENT AND LOW EMISSIVITY
COATINGS AND COATED ARTICLES**

CROSS-REFERENCE TO RELATED APPLICATION

5 This application claims the benefits of United
States Provisional Application No. 60/167,386, filed
November 24, 1999, entitled "LOW SHADING COEFFICIENT AND LOW
EMISSIVITY COATINGS AND COATED ARTICLES", which is herein
incorporated by reference.

10

FIELD OF THE INVENTION

 This invention relates generally to heat-reflective
and solar-control glazing materials such as multilayered
coatings and to articles, e.g. windows or insulating glass
15 units, incorporating such coatings and, more particularly, to
solar-control metal oxide-containing coatings which may form
solar-control articles having intermediate levels of luminous
(visible light) transmittance, relatively low shading
coefficient and emissivity, and acceptable levels of luminous
20 (visible light) reflectance.

DISCUSSION OF TECHNICAL CONSIDERATIONS

 In the design of buildings, architects are sometimes
asked to incorporate large amounts of windows into the
25 building design to increase the feeling of openness and light
and/or to achieve a particular exterior aesthetic. However,
windows are a major source of energy transfer either into or
out of a building's interior. Energy transfer across a window
glazing comprises: (1) heat flow into or out of a building due
30 to a difference between indoor and outdoor temperatures, and
(2) energy transfer into a building due to solar energy
transmitted and/or absorbed by the window glazing. The type
of glazing that is optimal for any climate depends upon what
energy transfer mechanisms have the most impact on the heating
35 and/or cooling costs of the building and the respective

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lengths of the cooling and heating seasons in that geographic location.

Energy transfer due to the indoor-outdoor temperature difference is further subdivided into three different transport mechanisms: (a) conduction through the glazing and its gas contents, (b) convection associated with the movement of gases (e.g. air) at all surfaces of the glazing, and (c) thermal radiation from the surfaces of the various glazing materials. In order to reduce energy transfer across window glazings, multi-pane insulating glass (IG) units have been developed. Such multi-pane IG units inhibit energy transfer via conduction and convection pathways by creating an insulating gas pocket. However, the instant invention is most germane to energy transfer caused by thermal radiation and direct solar heat gain. Hereinafter, we therefore direct our discussion of energy transfer mostly to thermal radiation and direct solar heat gain rather than that due to conduction or convection. Of course the latter two energy transfer pathways should always be considered in building glazing design.

Considering thermal radiation and direct solar heat gain, mainly in warm climates, energy enters into the building through the window glazing via several energy mechanisms. These include: (1) long-wave thermal infrared (IR) energy (i.e. heat) radiated from hot exterior surfaces such as pavement and buildings, and (2) the shorter wavelength ultraviolet, visible, and near infrared (or "solar infrared") radiation from the sun. The first is due to the fact that the outdoor temperature is higher than the indoor temperature. The second is either directly transmitted through the window or is first absorbed by the window glazing materials and then partially re-radiated into the interior space of the building. It is relevant to note that nearly all of the incident solar energy at the earth's surface falls almost approximately equally within the visible and solar infrared portions of the spectrum with a much smaller portion falling in the

ultraviolet. The heat load contribution from the solar ultraviolet is much less than the amount of energy in the visible and solar infrared.

In cold climates, interior heat is lost through the windows thereby increasing the energy costs required to maintain a desired interior temperature. This loss is because the indoor temperature is higher than the outdoor temperature. In the case of cold climates, the heat loss due to the indoor-outdoor temperature difference is partially offset by the desirable passive solar heating of the interior space during daylight hours.

Radiative energy loss from a surface is governed by the surface's emissivity. Emissivity relates to the propensity of the surface to radiate energy. For surfaces near room temperature, this radiated energy falls within the long-wavelength thermal infrared portion of the electromagnetic spectrum. High-emissivity surfaces are good thermal radiators; a blackbody is a perfect radiator and is defined as having an emissivity of unity ($e = 1$). In comparison, uncoated clear float glass has an emissivity of about 0.84, which is only around 16 percent less than a black body.

Radiative energy transfer across a window glazing can be inhibited by reducing the emissivity of one or more surfaces of the glass. This emissivity reduction can be realized by the use of so-called "low emissivity" or "low-E" coatings applied to the glass surface(s). Low emissivity coated glasses are attractive for architectural windows since they significantly reduce the costs of heating a building in cold climates. These low-E coatings typically comprise multilayer thin film optical stacks. The optical stacks are designed to have high reflectance in the long-wavelength thermal infrared thereby inhibiting heat transfer due to radiation across the glazing whilst retaining a high level of luminous transmittance and low luminous reflectance in the

shorter-wavelength visible portion of the spectrum. In this manner the coated glass does not dramatically depart from the visual appearance of an uncoated pane of glass. Such coatings are typically referred to as "high-T/low-E" coatings. Over the past twenty years, the use of such spectrally-selective high-T/low-E coated glasses has achieved widespread marketplace acceptance in cool climates. In these climates the heating seasons are long and the passive solar heating achieved through the use of such high luminous transmittance coatings assists in counteracting heat loss due to indoor-outdoor temperature differences. One main type of such high-T/low-E coatings comprise one or more infrared-reflective layers (typically noble metals such as silver) sandwiched between dielectric layers (typically metal oxides or certain metal nitrides). Examples of low emissivity coatings are found, for example, in United States Patent Nos. 5,821,001; 5,028,759; 5,059,295; 4,948,677; 4,898,789; 4,898,790; and 4,806,220, which are herein incorporated by reference.

However, because conventional high-T/low-E windows generally transmit a relatively high percentage of visible light, and solar infrared ("near infrared") radiation to a somewhat lesser degree, use of such coatings can result in increased heat load to a building's interior in the summer season, thus increasing cooling costs. Although this problem is important for all types of buildings (such as residential homes) in warm climates, it is particularly acute for so-called "commercial" architecture; that is, buildings that house office space or other facilities primarily intended for the purposes of business and commerce like office towers, business parks, high-rise hotels, hospitals, stadiums, and tourist attractions. Conventional high-T/low-E coated glasses do impart some degree of heat load reduction in hot climates because the low-E coating reduces the thermal infrared load from hot exterior surfaces into the building's interior. However they do not shade the building's interior as

effectively from directly transmitted and absorbed solar energy.

As a point of terminology, the ability of a window glazing to shade the interior space from transmitted and absorbed solar energy is characterized by a parameter known as the glazing's "shading coefficient" (hereinafter referred to as "SC"). The term "shading coefficient" is an accepted term in the field of architecture. It relates the heat gain obtained when an environment is exposed to solar radiation through a given area of opening or glazing to the heat gain obtained through the same area of 1/8 inch (3 mm) thick single-pane clear uncoated soda lime silicate glass under the same design conditions (ASHRAE Standard Calculation Method). The 1/8 inch thick clear glass glazing is assigned a shading coefficient of SC = 1.00. A shading coefficient value below 1.00 indicates better heat rejection than single-pane clear glass. A value above 1.00 would be worse than the baseline clear single pane glazing.

Conventional silver-based high-T/low-E coated glasses, briefly described above, typically have SCs of about 0.44 to about 0.70 and luminous (visible) light transmittance of about 71% to about 75%. All of these values are referenced to a double-glazed IG unit installation having clear glass substrates. With such SCs, conventional high-T/low-E coated glasses are less optimal for hot climates.

What is needed and desirable, for at least hot climates as an object of the present invention are coatings to give transparency articles like window glazings (1) low-emissivity to inhibit heat ingress from the hot exterior via thermal radiation and, (2) low transmittance and/or low absorbance of direct solar radiation through the glazing. This should be accomplished while maintaining acceptable visible light transmission through the glazing.

SUMMARY OF THE INVENTION

The present invention is directed to a low emissivity, low shading coefficient, low reflectance multi-layer coating and coated article. The coating provides a coated article of a transparent or at least translucent substrate with a surface comprising the coating of: at least one antireflective layer deposited over a substrate surface; and at least one infrared reflective layer deposited over the at least one antireflective layer, such that the coated article comprises a visible light transmittance of greater than about 50%, a shading coefficient of less than about 0.33 and a luminous exterior and/or interior reflectance of less than about 30%. The coated article, e.g. an IG unit, also preferably has a substantially neutral color in reflectance and a blue or blue-gray color in transmission. The latter value is based or measured for a double-glazed IG unit employing clear glass substrates.

The multi-layer coating of the present invention is a middle-T/low-SC/low-E coating as opposed to a high-T/low-E type coating for transparencies. The "T" refers to luminous (visible) light transmittance and the "E" refers to emissivity. The middle-T is generally in the range of greater than about 50% and suitably about 50% to about 70%. The coating is comprised of several primary layers that may be comprised of one or more films. These primary layers can be a first antireflective layer, a first infrared reflective layer, a first primer layer, second antireflective layer, second infrared reflective layer, second primer layer, and a third antireflective layer. Optionally the one or more protective overcoats can be present. These layers are arranged predominantly in the order stated one on top of the other over a substantial portion if not all of one or more surfaces of the substrate. Any portion of the surface of the substrate can be coated. Suitably when at least one surface of the substrate that is exposed to light is coated, increased

benefits from the invention are realized. The aforementioned layers of the inventive coating are primary layers in that other films or layers can be between the layers themselves or the stacks of the layers as long as these secondary layers or
5 films do not interfere with the functioning of the primary layers.

The thickness of the layers of the coating is such that the individual infrared reflective layers are not increased to be greater than that for high-T/low-E coatings.
10 Increasing the thickness of the infrared reflective layer like silver layer(s) much beyond that for high T/low E coatings both increases the long-wavelength thermal infrared reflectivity and increases the shorter-wavelength solar infrared reflectivity. Even though the latter lowers the
15 shading coefficient, the former reduces emissivity. Also in regards to the spectral characteristics of the infrared reflective layers, like silver thin films, simply increasing the thickness of the silver layer or film will simultaneously tend to increase the coating's reflectance and decrease the
20 coating's transmittance in the visible region of the electromagnetic spectrum. This is an important aesthetic issue concerning the variation of reflected and transmitted colors of the coated article with the angle of observation. Such thicker silver layer(s) will tend to produce coatings
25 that acquire reflected colors having unacceptable red or pink or orange components viewed either at normal incidence or at an oblique (grazing) angle.

Also in the present invention the thickness of the individual antireflective layers adjacent to the infrared
30 reflective layers are not offset to some extent to compensate for any increased visible reflectance and decreased visible transmittance from any such increased thickness of the infrared reflective layers. Such modification of the physical (and therefore optical) thickness of the adjacent dielectric
35 layers (antireflective layer) to anti-reflect the silver

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layer(s) in the visible and to adjust the transmitted and reflected color of the coated article is possible. Although an improvement may be viewed at normal incidence, the reflected color viewed at oblique incidence may remain objectionable, or vice versa. However, the optical characteristics of real thin film dielectric materials impose constraints on the efficacy of such an anti-reflection approach.

The coated article of the present invention is a transparent or translucent substrate usually with two major surfaces as in the form of a flat, contoured, or curved sheet with the aforementioned coating on at least one of the surfaces. Also an embodiment of the present invention is an insulated glass unit (hereinafter referred to as "IG-unit"). In the IG-unit at least two transparent substrates are sealed together with a space or gap between them generally for transparent insulating materials usually of a gaseous nature. The IG-unit can have any surface of the substrate with the aforementioned coating but suitable surfaces are either or both of the interior surfaces of the IG-unit. Also the coating could be arranged on one or more polymeric films or foils that is placed in the gap in the IG-unit. When the coating is disposed on the surface of the transparent substrate in an IG-unit the coating can be on at least one of the surfaces but preferably is on one of the surfaces facing the gap. The substrates in the IG-unit can be clear or tinted or colored transparent or translucent glass or plastic. For instance the coating can be on one of the interior surfaces of a substrate in the IG-unit which is clear or colored or tinted and the other substrate without the coating can be tinted or colored glass or plastic rather than clear or untinted or uncolored.

The present invention accounts for the interdependence of solar performance, emissivity, and normal/oblique aesthetics, and in view of the limitations of

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real thin film optical materials, meets the challenge of producing a low-emissivity, solar-control coating having acceptable aesthetics. Such an article with such a coating can maintain acceptable aesthetics for transparencies for architectural, automotive, aerospace, or other such applications.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view, not to scale, of a coating incorporating features of the invention; and

Fig. 2 is a cross-sectional view of an IG unit incorporating features of the invention.

DESCRIPTION OF THE INVENTION

For purposes of the following discussion, the phrase "deposited over" means deposited above but not necessarily adjacent to. Additionally, directional terms such as "left", "right", "inner", "outer", "upper", "lower", etc., and similar terms shall relate to the invention as it is shown in the drawing figures. However, it is to be understood that the invention may assume various alternative orientations. Hence, such terms are not to be considered as limiting. Also, the terms "coating" or "coating stack" include one or more coating layers and/or coating films. The terms "coating layer" or "layer" include one or more coating films. Also patents and published patent documents listed in this disclosure are hereby incorporated by reference in total and specifically for that which the patents are noted as teaching. Additionally in the following discussion the numerical ranges or values for the percentage of materials and for the thickness of all of the individual layers and films and coatings are approximate and may vary slightly below the lower limit and above the upper limit or around the specifically stated number as though preceded by the word "about" for each.

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A substrate 10 having a low emissivity, low shading coefficient coating 12 incorporating features of the invention is generally shown in Fig. 1. The substrate 10 may be of any material but in the practice of the invention is preferably a transparent substrate, such as glass, plastic or ceramic. However, tinted or colored substrates may also be used. In the following discussion, the substrate 10 is preferably glass. Examples of glass suitable for the practice of the invention are described, for example, in United States Patent Nos. 4,746,347; 4,792,536; 5,240,886; 5,385,872; and 5,393,593.

The coating 12 is a multilayer coating and is deposited over at least a portion of the substrate surface in conventional manner. For example, the coating 12 may be applied by magnetic sputter vapor deposition (MSVD), chemical vapor deposition (CVD), spray pyrolysis, sol-gel, etc. In the currently preferred practice of the invention, the coating 12 is applied by MSVD. MSVD coating techniques are well known to one of ordinary skill in the glass coating art and hence will not be discussed in detail. Examples of MSVD coating methods are found, for example but not to be considered as limiting, in U.S. Patent Nos. 5,028,759; 4,898,789; 4,948,677; 4,834,857; 4,898,790; and 4,806,220.

The coating 12 includes a base layer or first antireflective layer 14 deposited over at least a portion of one of the substrate surfaces. The first antireflective layer 14 preferably comprises one or more films of dielectric materials or antireflective materials such as metal oxides or oxides of metal alloys which are preferably transparent or substantially transparent. Examples of suitable metal oxides include oxides of titanium, hafnium, zirconium, niobium, zinc, bismuth, lead, indium and tin and mixtures of any or all of these. These metal oxides may have small amounts of other materials, such as manganese in bismuth oxide, indium in tin oxide, etc. Additionally, oxides of metal alloys, such as

zinc stannate or oxides of indium-tin alloys can be used. Further, doped metal oxides, such as antimony-, fluorine- or indium-doped tin oxides or mixture thereof can be used. In the practice of the invention, the first antireflective layer 5 14 preferably comprises one or more oxides of zinc and tin. The first antireflective layer 14 may be a substantially single phase film such as zinc stannate or may be a mixture of phases composed of zinc and tin oxides or may be composed of a plurality of metal oxide films, such as those disclosed in 10 U.S. Patent No. 5,821,001. Preferably, the first antireflective layer 14 comprises one or more oxides of zinc and tin, e.g. zinc stannate. The first antireflective layer 14 preferably has a thickness in the range of 272 to 332 Angstroms, more preferably around 293 Angstroms. In a 15 currently preferred embodiment of the invention, the first antireflective layer 14 is a multifilm structure as disclosed in U.S. Patent No. 5,821,001 having a zinc stannate film deposited over the substrate surface and a zinc oxide film deposited over the zinc stannate film. The zinc stannate film 20 is sputtered using a zinc-tin cathode which is 52 wt% zinc and 48 wt% tin. The zinc oxide film is deposited from a zinc cathode having 10 wt% or less of tin. The zinc oxide film has a preferred thickness of 20 to 70 Angstroms in the layer as disclosed in U.S. Patent No. 5,821,001. It is also possible 25 that the zinc oxide film may be less than this thickness or may be omitted entirely thereby rendering the first antireflective layer 14 a single zinc stannate film.

A first IR reflective layer 16 is deposited over the first antireflective layer 14. The first IR reflective layer 30 16 is preferably an IR reflective metal, such as gold, platinum, copper, silver, or alloys or mixtures of any or all of these that are IR reflective. In the preferred embodiment of the invention, the first IR reflective layer 16 comprises silver and preferably has a thickness in the range of 80 to 35 269 Angstroms, more preferably 86 Angstroms.

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A first primer layer 18 which is preferably at least one film is deposited over the first IR reflective layer 16. The first primer layer 18 is a material and deposited at such a thickness to minimize exposure of the silver layer to
5 reaction from a subsequently applied reactive plasma for film or layer deposition. Preferably the primer layer is at least one oxygen capturing film, such as titanium, that is sacrificial during the deposition process to prevent degradation of the first IR reflective layer 16 during the
10 sputtering process. The first primer layer 18 preferably has a thickness of 8 to 30 Angstroms, most preferably 8 to 20 Angstroms as disclosed in U.S. Patent No. 5,821,001. For tempering of glass, the thickness of the primer layer can be increased and the thickness of the other layers can be altered
15 to match or exceed the aesthetics and/or performance of the untempered glass.

A second antireflective layer 20 is deposited over the first primer film 18. The second antireflective layer 20 preferably comprises one or more metal oxide or metal alloy
20 oxide films, such as those described above with respect to the first antireflective layer 14. In the currently preferred practice of the invention, the second antireflective layer 20 has a first film of zinc oxide deposited over the first primer film 18. A zinc stannate film is deposited over the first
25 zinc oxide film and a second zinc oxide film is deposited over the zinc stannate film to form a multi-film antireflective layer. Each zinc oxide film of the second antireflective layer 20 is preferably 20 to 70 Angstroms thick, although the zinc oxide film may be less than this thickness. The second
30 antireflective layer 20 preferably has a total thickness of 698 to 863 Angstroms, more preferably 719 Angstroms.

A second IR reflective layer 22 is deposited over the second antireflective layer 20. The second IR reflective layer 22 is preferably silver and most preferably a silver
35 film although any of the materials listed for the first IR

reflective layer 16 and has a thickness of 159-257 Angstroms, more preferably 170 to 180 Angstroms.

A second primer layer 24 is deposited over the second IR reflective layer 22. The second primer layer 24 is preferably titanium having a thickness of 8-20 Angstroms.

A third antireflective layer 26 is deposited over the second primer layer 24. The third antireflective layer 26 is also preferably one or more metal oxide or metal alloy oxide containing films such as discussed above with respect to the first antireflective layer 14. In practice, the third antireflective layer 26 includes a zinc oxide film of 20 to 70 Angstroms deposited over the second primer layer 24 as disclosed in U.S. Patent No. 5,821,001. However the zinc oxide film may be less than this thickness or may be omitted entirely and a zinc stannate film can be deposited over this zinc oxide film. The third antireflective layer 26 has a total thickness of 60-273 Angstroms, preferably 115 Angstroms.

A protective overcoat 28 is deposited over the third antireflective layer 26 to provide protection against mechanical and chemical attack. The protective overcoat 28 is preferably an oxide of titanium like titanium dioxide having a thickness of 30-45 Angstroms. Alternatively or in addition thereto, a protective coating, such as one or more oxides or oxynitrides of silicon or one or more oxides of aluminum or mixtures or combinations of any of these, may be deposited over the titanium dioxide coating or in lieu thereof.

Examples of suitable protective coatings are disclosed, for example, in U.S. Patent Application No. 09/058,440 and in U.S. Patent Nos. 4,716,086; 4,786,563; 4,861,669; 4,938,857; and 4,920,006 and Canadian Application No. CA 2,156,571. In lieu of or in addition to the protective overcoat 28, temporary or removable protective films, layers or coatings can be used such as solvent soluble organic coatings like those describe in U.S. Patent Application Serial Number 09/567934, filed 10-May-2000, and similar to PCT application number WO US00/17326

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outwardly facing or outer surface 54 and an inwardly facing or inner surface 56. The multi-layer coating 12 of the invention is preferably deposited either on the inner surface 52 of the exterior glass piece 42, as shown in Fig. 2, or the outer surface 54 of the interior glass piece 44. As discussed hereinbelow, the IG unit 40 having the coating 12 of the invention provides a visible light transmittance of greater than about 50%, preferably 55%; a shading coefficient of less than about 0.33; and an exterior reflectance of less than about 30% when normally positioned, e.g. the outer surfaces directed to the exterior of the structure and the inner surfaces directed to the interior of the structure.

EXAMPLES

Coatings were prepared in accordance with the invention and analyzed for optical qualities. The coating layers were deposited at the specified thickness as shown in Table I on pieces of clear float glass of the thickness shown in Table I by MSVD for an IG unit. In the IG unit the coated glass was as reference number 44 and the coating as reference number 54 in Fig, 2. The structure of the coated samples is given in Table I, with the layer thickness given in Angstroms. In each sample, the first, second and third antireflective layers (AR layers) were multifilm zinc oxide and zinc stannate structures as described above. The numbers in Table I are for the total thickness of the specific layers, with each individual zinc oxide film in an AR layer being about 50 to 60 Angstroms thick. The first and second IR reflective layers (IR layers) were silver and the primer layers were titanium. The overcoat was titanium dioxide. The notation ND means that no data was taken.

Table I

Sample No.	Glass thickness inch	1 st AR	Ag	Ti	2 nd AR	2 nd Ag	Ti	3 rd AR	Over-coat
1	0.1596	332	128	15	771	246	15	168	45
2	0.0862	312	236	15	698	159	15	202	45
3	0.0863	272	236	15	845	192	15	196	45
4	0.0863	313	246	15	863	210	15	250	45
5	0.126	300	86	13	714	175	13	123	30
6	0.126	300	86	13	714	175	13	60	30
7	0.125	300	95	13	734	184	13	98	30
8	0.126	300	103	13	808	202	13	194	30
9	0.126	300	107	13	734	167	13	98	30
10	0.126	300	103	13	714	184	13	98	30
11	0.124	293	80	17	719	178	15.5	105	43
12	0.123	293	86	17	695	178	15.5	105	43
13	0.125	293	86	17	719	178	15.5	115	43

The optical and performance characteristics of the samples of Table I are shown in Table II. The optical characteristics in Table II are calculated values ("center of glass") for either a monolithic piece of glass or an IG unit incorporating the respective sample coatings. These calculations used the spectrophotometric data and the "WINDOW" 4.1 simulation software program available from Lawrence Berkeley National Laboratory. All of the optical characteristics in Table II, with the exception of LCS, are standard and well known terms in the glass industry. The term "LCS" refers to a light to cooling selectivity index and is defined as the percent visible light transmittance (expressed as a decimal) divided by the shading coefficient.

Table II

Sample No.	% vis	% ext vis reflect-ance	% int vis reflect-ance	Summer shading coefficient	Solar heat gain coefficient	LCS	LHS	Emissivity	Winter U-value
1	55.2	21.8	29.2	0.29	0.25	1.90	2.21	0.03	0.24
2	56.8	25.3	20.4	0.29	0.25	1.96	2.27	0.029	0.29
3	57.2	25.7	24.5	0.29	0.25	1.97	2.29	0.041	0.30
4	58.9	23.8	22.3	0.29	0.25	2.03	2.36	0.039	0.30
5	56.7	21.9	29.1	0.33	0.28	1.72	2.03	0.032	0.29
6	51.2	26.3	35.5	0.30	0.25	1.71	2.05	0.032	0.29
7	53.1	24.7	33	0.30	0.26	1.77	2.04	0.033	0.29
8	54.1	25.5	31.8	0.30	0.26	1.80	2.08	0.029	0.29
9	58.6	19.8	26.6	0.32	0.28	1.83	2.09	0.031	0.29
10	53.2	22.2	31.6	0.29	0.25	1.83	2.13	0.029	0.29
11	54.3	25.1	32.5	0.32	0.27	1.70	2.01	0.029	0.29
12	55.0	23.4	31.4	0.31	0.27	1.77	2.04	0.048	0.30
13	56.0	23.5	30.6	0.32	0.28	1.75	2.00	0.048	0.30

Table III shows several listed physical parameters for monolithic glass samples coated with coating of Table I and listed performance data for these glasses.

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Table III

Monolithic Performance Data (all data are center-of-glass)

Sample ID	clear glass thickness (inch)	visible transmittance (%)	glass-side visible reflectance (%)	coating-side visible reflectance (%)	TSET (%)	TSER-glass-side (%)	TSER-coating-side (%)	summer shading coefficient (energy incident on coated surface)	solar heat gain coefficient (energy incident on coated surface)	LCS	LHS	coated surface emissivity
1	0.1596	60.3	18.6	25.3	28.2	37.9	60.7	0.38				0.030
2	0.0862	62.1	21.9	14.2	25.3	51.3	59.2	0.35	0.30	1.77	2.07	0.029
3	0.0863	62.3	22.3	18.9	25.1	51.3	60.2	0.35	0.30	1.78	2.08	0.041
4	0.0863	64.2	20.2	16.4	24.8	51.7	60.7	0.34	0.30	1.89	2.14	0.039
5	0.126	61.8	18.6	25.0	27.5	40.0	61.5	0.36	0.31	1.72	1.99	0.032
6	0.126	55.4	23.5	32.5	24.6	42.3	65.4	0.32	0.28	1.73	1.98	0.032
7	0.125	57.6	21.8	29.6	24.7	42.7	65.0	0.33	0.28	1.75	2.06	0.033
8	0.126	58.8	22.5	28.1	25.1	42.4	61.1	0.33	0.29	1.78	2.03	0.029
9	0.126	64.0	16.2	21.9	27.1	40.6	61.6	0.36	0.31	1.78	2.06	0.031
10	0.126	57.8	19.2	27.9	23.8	43.4	65.8	0.32	0.27	1.81	2.14	0.029
11	0.124	58.9	22.0	29.0	26.8	40.9	62.8	0.35	0.30	1.68	1.96	0.029
12	0.123	59.7	20.3	27.7	26.4	41.4	63.2	0.35	0.30	1.71	1.99	0.048
13	0.125	60.9	20.3	26.8	27.2	40.9	62.3	0.35	0.31	1.74	1.96	0.048

The results of mechanical and chemical durability tests conducted on the samples are shown in Table IV.

Table IV							
Sample No.	Initial Haze	Salt Test	Ammonium Test	Acetic Acid	DART 210	CCC	Taber Test
1	ND	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND	ND
3	ND	ND	ND	ND	ND	ND	ND
4	ND	ND	ND	ND	ND	ND	ND
5	12.0	9.0	10.0	9.0	9.5	8.5	65
6	11.0	8.5	9.0	8.5	9.0	7.0	ND
7	11.0	9.0	9.5	9.5	9.0	9.0	62
8	11.0	9.0	9.0	9.5	9.0	8.5	ND
9	11.0	9.0	9.0	9.5	8.5	9.0	63
10	11.0	8.5	9.0	8.0	8.5	6.0	ND
11	9.0	9.0	9.0	9.5	9.0	9.0	58
12	9.5	9.0	9.0	9.0	9.5	9.0	56
13	9.3	9.0	9.3	9.5	9.0	9.3	63

The haze ratings shown in Table IV are based on a twelve unit system, with twelve being substantially haze free and lower numbers indicating increasing levels of haze. In the following discussion unless indicated to the contrary, the observation for haze was performed as follows. A coated piece of glass ("coupon") was treated in accordance with the particular test being conducted. The coupons were individually observed with the unaided eye in a dark room with about 150 watt flood light. The coupon was placed in front of the light, and its position was adjusted relative to the light to maximize haze. The observed haze was then rated.

The salt water test consists of placing the coated glass pieces or coupons in a 2.5 weight percent (wt%) solution of sodium chloride in deionized water for 2.5 hours. The

coupons were removed, rinsed in deionized water and dried with pressurized nitrogen and then rated for haze.

In the ammonium hydroxide test a test coupon was placed in a 1 Normal solution of ammonium hydroxide in deionized water at room temperature for 10 minutes. The coupon was removed from the solution, rinsed in deionized water and dried as discussed above. The test coupon was examined for haze.

In the acetic acid test a test coupon was submerged in a 1 normal solution of acetic acid in deionized water at room temperature for 10 minutes. The test coupon was removed from the solution and rinsed off with deionized water and blown dry using high pressure nitrogen. The test coupon was examined for haze.

The Cleveland Condensation Chamber (CCC) test is a well-known test and is not discussed in detail herein. The test coupons were exposed to the CCC test for a period of time with warm water vapor and examined for haze. The abbreviation "ND" stands for "no data".

The Taber test is also a well known test and will not be described in detail. Generally the modified Taber test comprises securing the sample to be tested on a flat, circular turntable. Two circular, rotating Calibrase® CS-10F abrasive wheels (commercially available from Taber Industries of N. Tonawanda, NY) are lowered onto the top surface of the sample to be tested; there is a load of 500 grams applied to each abrasive wheel. The Calibrase® CS-10F wheels are an elastomeric-type material that is impregnated with an abrasive. To conduct the test, the turntable is switched "ON" and the abrasive wheels turn and abrade the sample's surface as the sample and turntable rotate about a vertical axis until the desired number of rotations or "cycles", here 10, is completed. After testing, the sample is removed from the turntable and examined for damage to the top surface. The numbers in Table IV denote the scratch density per square

millimeter for a black and white micrograph at a 50X magnification.

Thus, the present invention provides a low emissivity, solar control article, e.g. an IG unit, having
5 visible light transmission of greater than about 50%, a shading coefficient less than about 0.33 and an exterior reflectance less than about 30%. Such an article is particularly well adapted for use in warmer climates to help reduce cooling costs for the interior of a structure.

10 In a preferred embodiment, a solar control coated article of the invention comprises a substrate with a first antireflective layer deposited over at least a portion of the substrate. A first infrared reflective film is deposited over the first antireflective layer and a first primer film is
15 deposited over the first infrared reflective film. A second antireflective layer is deposited over the first primer film and a second infrared reflective film is deposited over the second antireflective layer. A second primer film is deposited over the second infrared reflective film and a third
20 antireflective layer is deposited over the second primer film, such that the coated article has a transmittance greater than about 55%, a shading coefficient of less than about 0.33 and a reflectance of less than about 30%. A protective overcoat, e.g. an oxide or oxynitride of titanium or silicon, may be
25 deposited over the third antireflective film.

It will be readily appreciated by those skilled in the art that modifications may be made to the invention without departing from the concepts disclosed in the foregoing description. Such modifications are to be considered as
30 included within the scope of the invention. Accordingly, the particular embodiments described in detail hereinabove are illustrative only and are not limiting as to the scope of the invention, which is to be given the full breadth of the above disclosure and any and all equivalents thereof.

What is claimed is:

1. A solar control article, comprising:
a substrate having a surface;
at least one antireflective layer deposited over the
5 substrate surface; and
at least one infrared reflective film deposited over
the at least one antireflective layer,
such that the coated article has a transmittance
greater than about 55%, a shading coefficient less than about
10 0.33 and a reflectance less than about 30%.

2. The article as claimed in claim 1, wherein the
article includes a first antireflective layer, a second
antireflective layer, a third antireflective layer, a first
15 infrared reflective layer and a second infrared reflective
layer, with the first infrared reflective layer deposited over
the first antireflective layer and the second infrared
reflective layer deposited over the second antireflective
layer and with the third antireflective layer deposited over
20 the second infrared reflective layer.

3. The article as claimed in claim 2, including a
first primer layer deposited over the first infrared
reflective layer and a second primer layer deposited over the
25 second infrared reflective layer.

4. The article as claimed in claim 2, wherein the
antireflective layers include metal-oxide films selected from
one or more metal oxides, oxides of metal alloys, doped metal
30 oxides and mixtures thereof.

5. The article as claimed in claim 2, wherein the
one or more metal oxides are selected from zinc oxide,
titanium oxide, hafnium oxide, zirconium oxide, niobium oxide,
35 bismuth oxide, indium oxide, tin oxide and mixtures thereof.

6. The article as claimed in claim 2, wherein the metal alloys are selected from the group consisting of zinc stannate, tin alloys, fluorine doped tin, antimony doped tin, and indium-tin alloys.

7. The article as claimed in claim 2, wherein at least one of the antireflective layers comprises a plurality of antireflective films.

8. The articles as claimed in claim 2, wherein the infrared reflective films include at least one metal selected from the group consisting of gold, copper, platinum, and silver and mixtures thereof.

9. The article as claimed in claim 2, wherein the first antireflective layer has a thickness of about 272 to about 332 angstroms, the second antireflective layer has a thickness of about 198 to about 836 angstroms and the third antireflective layer has a thickness of about 60 to about 273 angstroms.

10. The article as claimed in claim 2, wherein the first infrared reflective layer has a thickness of about 86 to about 269 angstroms and the second infrared reflective layer has a thickness of about 159 to about 257 angstroms.

11. The article as claimed in claim 3, wherein the first and second primer layers each have a thickness of about 15 to about 30 angstroms.

12. The article as claimed in claim 2, wherein the thickness of the second infrared reflective layer is about 50 to about 100% greater than the thickness of the first infrared reflective layer.

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18. The article as claimed in claim 16, wherein the article has a transmittance greater than about 55%, a shading coefficient of less than about 0.32 and an external reflectance less than about 20%.

5

19. The article as claimed in claim 16, wherein the substrate is selected from the group consisting of glass, plastic and ceramic.

10

20. The article as claimed in claim 16, wherein the antireflective films include a metal oxide film selected from the group consisting of metal oxides, metal alloys, doped metal oxides and mixtures thereof.

15

21. The article as claimed in claim 20, wherein in the metal oxides are selected from the group consisting of zinc oxide, titanium oxide, hafnium oxide, zirconium oxide, niobium oxide, bismuth oxide, indium oxide, tin oxide and mixtures thereof.

20

22. The article as claimed in claim 20, wherein the metal alloys are selected from the group consisting of zinc stannate, fluorine doped tin, antimony doped tin, and indium-tin alloys.

25

23. The article as claimed in claim 20, wherein the doped metal oxides are selected from the group consisting of antimony doped tin oxide and indium doped tin oxide.

30

24. The article as claimed in claim 16, wherein the first infrared reflective layer includes a metal from the group consisting of gold, copper, platinum, and silver and mixtures thereof.

25. The article as claimed in claim 16, where at least one of the first, second, or third antireflective layers includes a plurality of antireflective films.

5 26. The article as claimed in claim 16, wherein the primer layer includes titanium.

10 27. The article as claimed in claim 16, including a protective, metal containing overcoat deposited over the third antireflective layer.

 28. The article as claimed in claim 16, wherein the article is an insulated glass unit.

15 29. The article as claimed in claim 16, wherein the first antireflective layer has a thickness of about 272 to about 332 angstroms, the second antireflective layer has a thickness of about 198 to about 836 angstroms and the third antireflective layer has a thickness of about 60 to about 273
20 angstroms.

 30. The article as claimed in claim 16, wherein the first infrared reflective layer has a thickness of about 86 to about 269 angstroms and the second infrared reflective layer
25 has a thickness of about 159 to about 257 angstroms.

 31. The article as claimed in claim 16, wherein the first and second primer layers each have a thickness of about 15 to about 30 angstroms.

30

 32. A method of making a solar control article, comprising the steps of:
 providing a substrate having a surface;
 depositing at least one antireflective layer
35 over the substrate surface; and

depositing at least one infrared reflective layer over the at least one antireflective layer such that the coated article has a transmittance greater than about 55%, a shading coefficient less than about 0.33 and a reflectance less than about 30%.

33. The method as claimed in claim 32, including depositing a first infrared reflective film over a first antireflective layer, depositing a second infrared reflective film over a second antireflective layer and depositing a third antireflective layer over the second infrared reflective film.

34. The method as claimed in claim 32, including depositing a first primer film over the first infrared reflective film and depositing a second primer film over the second infrared reflective film.

35. The method as claimed in claim 32, wherein the article has a substantially neutral color.

36. The article as claimed in claim 32, wherein the antireflective layer depositing step is practiced by depositing a plurality of antireflective films to form the at least one antireflective layer.

37. The method as claimed in claim 33, wherein the first infrared reflective film has a thickness of about 86 to about 269 angstroms and the second infrared reflective film has a thickness of about 159 to about 257 angstroms.

38. The method as claimed in claim 34, wherein the first and second primer films each have a thickness of about 15 to about 20 angstroms.

ABSTRACT OF THE DISCLOSURE

5 The present invention is directed to a low emissivity, low shading coefficient, low reflectance multi-layer coating and coated article having a visible light transmittance of greater than about 50%, preferably greater than about 55%, a shading coefficient of less than about 0.33 and an exterior reflectance of less than about 30%. The coated article, e.g. an IG unit, has a substrate with a first antireflective layer deposited over the substrate. A first
10 infrared reflective layer is deposited over the first antireflective layer and a first primer layer is deposited over the first infrared reflective layer. A second antireflective layer is deposited over the first primer layer and a second infrared reflective layer is deposited over the
15 second antireflective layer. A second primer layer is deposited over the second infrared reflective layer and a third antireflective layer is deposited over the second primer layer, such that the coated article has a transmittance greater than about 55%, a shading coefficient of less than
20 about 0.33 and a reflectance of less than about 30%. A protective overcoat, e.g. an oxide or oxynitride of titanium or silicon, and/or solvent soluble organic film former may be deposited over the third antireflective layer.

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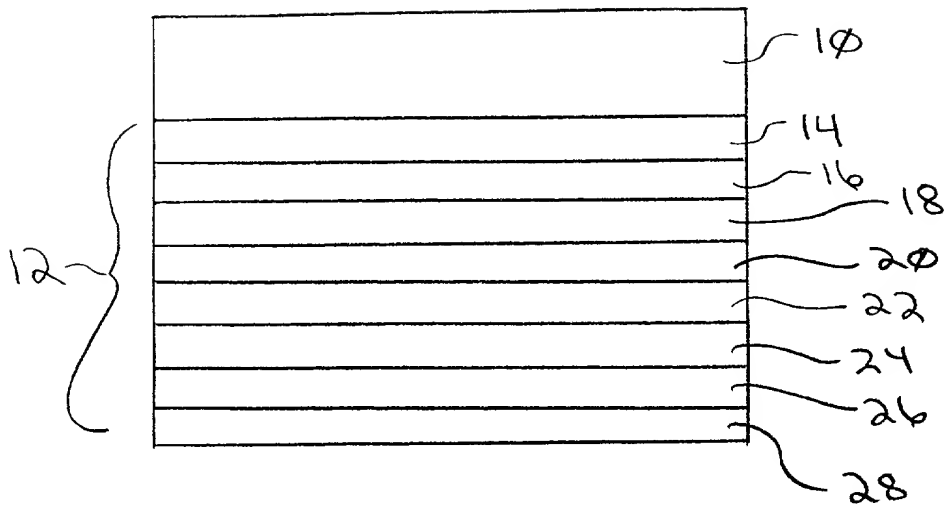


Fig. 1

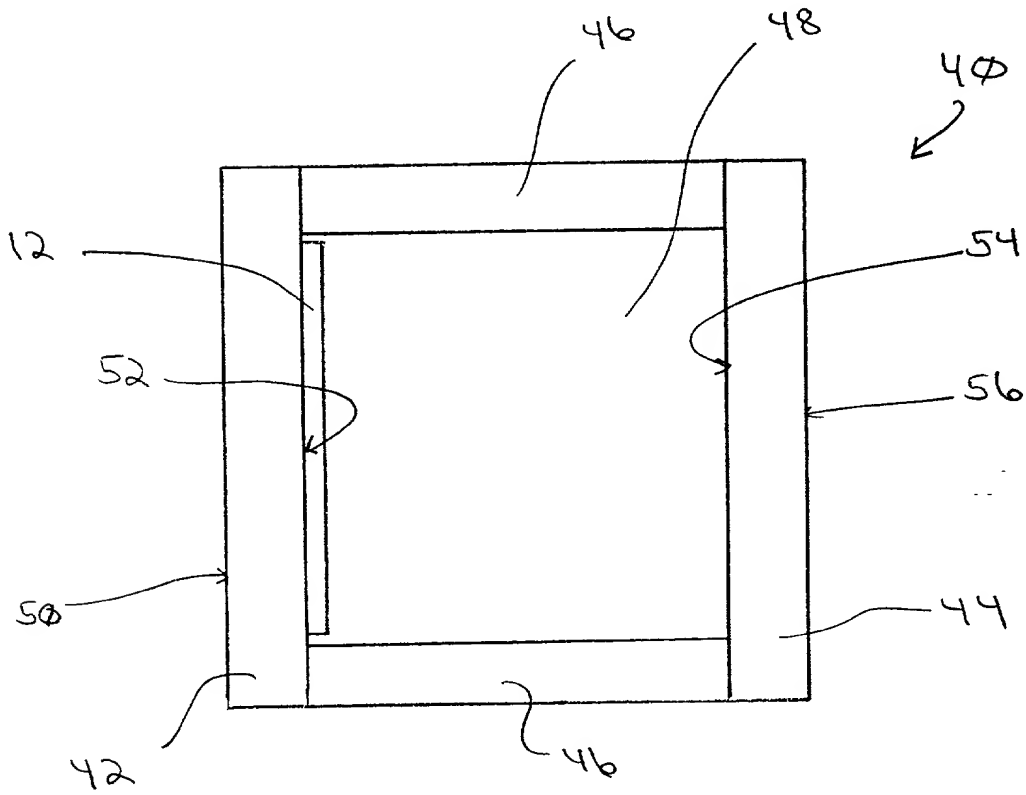


Fig. 2

Docket No.
1559A1

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

LOW SHADING COEFFICIENT AND LOW EMISSIVITY COATINGS AND COATED ARTICLES

the specification of which

(check one)

☒ is attached hereto.

☐ was filed on _____ as United States Application No. or PCT International Application Number _____

and was amended on _____
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Priority Not Claimed

_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/>
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/>
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/>

November 24, 1999

(Application Serial No.)

(Filing Date)

(Application Serial No.)

(Filing Date)

(Application Serial No.)

(Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application Serial No.)

(Filing Date)

(Status)
(patented, pending, abandoned)

(Application Serial No.)

(Filing Date)

(Status)
(patented, pending, abandoned)

(Application Serial No.)

(Filing Date)

(Status)
(patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

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Post Office Address	

Full name of sixth inventor, if any	
Sixth inventor's signature	Date
Residence	
Citizenship	
Post Office Address	